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Notes and Comments

Hemispheric Difference in Human Skin Color

George Chaplin
and Nina G. Jablonski*

Department of Anthropology, California Academy of Sciences, Golden Gate Park, San Francisco, California 94118-4599

In this journal, Relethford (1997) demonstrated that a regression of human skin color and latitude produced different values for the Southern and Northern Hemispheres. From this he reasoned that human skin was darker in the Southern than in the Northern Hemisphere at equivalent latitude and suggested that these differences may be due to hemispheric differences in ultraviolet (UV) radiation. He cited several factors that may have contributed to differences in UV radiation between the hemispheres, including ozone concentration, atmospheric turbudity, and the perihelion effect. (Perihelion, or the minimum earth–sun distance, currently occurs on 3 January, during the austral summer). It is suggested here that these are not the only causes of the effect that Relethford documented. The contribution of geography itself, specifically the relative sizes of the land masses in the Southern and Northern Hemispheres receiving the greatest mean UV exposure, must be considered.

To examine Relethford's claim that differences in skin color between the hemispheres were due to differences in levels of UV radiation, a large data set of erythemally weighted daily UV exposures at the earth's surface were analyzed. These data were derived from NASA's Total Ozone Mapping Spectrometer (TOMS) carried aboard the Nimbus-7 satellite between 1978 and 1993 (Herman and Celarier, 1996). They account for the total ozone column, scene reflectivities (albedo and cloud), terrain height, and the model action spectrum of UV erythemal susceptibility for Caucasoid skin. The data were measured for cells of 1.5° of longitude by 1° of latitude across the earth's surface between the two polar circles. The data set comprised 37,440 readings taken each day from 1979–1992. Because of the large size of the original data set (over 400 megabytes), the data were abridged for purposes of the present analysis. This was done by taking an average for all the years of the 22nd day of each month. For the equinoxes and solstices, the 21st through the 23rd days of the months were first averaged to make sure that the 22nd day was truly representative. Data analysis was undertaken using S-Plus 4.0 (MathSoft) and ArcView 3.0 with Spatial Analyst (Environmental Systems Research Institute).

TABLE 1. Percentage of the earth's land area falling within various latitudinal zones

Region	Area ($\times 10^6$ km^2)	Percentage
Above Arctic Circle	8.4	5.8
Northern hemisphere (non-tropics)	63.9	44.1
Northern tropics	26.5	18.3
Southern tropics	23.0	15.9
Southern hemisphere (non-tropics)	11.0	7.6
Antarctica	12.1	8.3
Total	144.9	100.0
Total Northern Hemisphere	98.8	68.2
Northern Hemisphere (minus land within Arctic Circle)	90.4	62.4
Total Southern Hemisphere	46.1	31.8
Southern Hemisphere (minus Antarctica)	34.0	23.4

It was found that the Northern Hemisphere (NH) and Southern Hemisphere (SH) had almost equal erythemal means of 195.7 and 195.1, respectively ($P = 0.6288$, standard two sample t-test), but the SH had significantly more active UV radiation at the summer solstice (SH = 293.3 versus

*Correspondence to: Dr. N. Jablonski, Department of Anthropology, California Academy of Sciences, Golden Gate Park, San Francisco, CA 94118-4599. Tel: (415) 221-5100. Fax: (415) 750-7346. E-mail: njablonski@cas.calacademy.org

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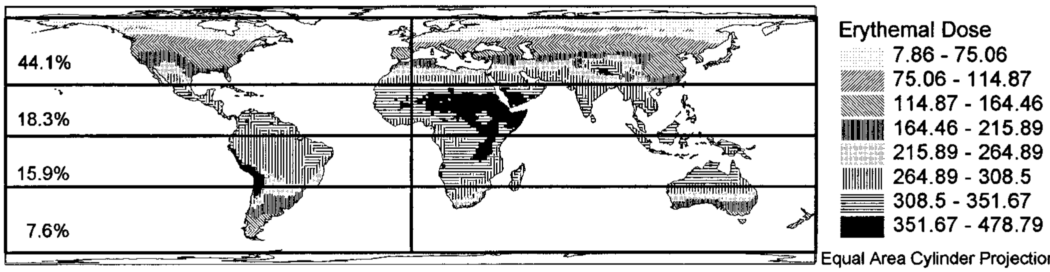

Fig. 1. Mean erythemally weighted UV exposure over the earth's land masses based on the summary of the satellite data from 1979–1992 described in the text. Note the differences between the hemispheres in the relative areas of land receiving the greatest mean UV exposure (solid black) versus those receiving the least (light gray stippling). In the Southern Hemisphere the areas receiving high annual UV exposures constitute a much larger percentage of the total habitable land area than in the Northern Hemisphere. Equal Area Cylindrical Projection.

NH = 274.8 [P = 0.0]) and the NH had more active UV radiation at the winter solstice (SH = 104.4 versus NH = 112.1 [P = 0.0]). This could be predicted by today's perihelion effect, but this situation, as Relethford noted, might not have been observed during the period when human skin colors were evolving because of unknown vagaries of the earth's past orbital characteristics.

Hemispheric differences in UV radiation may, however, have another explanation, related to differences between the hemispheres in the amounts of habitable land in respective latitudinal bands. The NH, including land north of the Arctic Circle, comprises approximately 98.8×10^6 km^2 of land surface, whereas the SH, including Antarctica, comprises only about 46.1×10^6 km^2 (Table 1). Excluding land north of the Arctic Circle and Antarctica, the land area for the NH is 90.4×10^6 km^2, whereas that for the SH is 34×10^6 km^2. Although these proportions have changed through the long course of geological time, they have been relatively stable over the course of the roughly 5 million year course of hominid evolution.

When the erythemally weighted daily UV exposures were computed for the hemispheric land areas, there was indeed a significant difference between the two hemispheres. It was found that the SH and NH had unequal annual means of 276.5 and 171.5, respectively (P = 0.0), and the SH had significantly more active UV at the summer solstice (SH = 356.0 versus NH = 270.5 [P = 0.0]). In addition, the SH at this time had more active UV at the winter solstice (SH = 158.8 versus NH = 88.4 [P = 0.0]). These results can be attributed to the concentration of land in the SH nearer to the equator (Fig. 1).

The latitudinal land mass bias presented here affects Relethford's regression analysis of skin color differences between the hemispheres, because the correlation of latitude and mean annual erythemal dose relative to land surface area land differs between hemispheres. For the year, it is r = 0.77 in the SH and r = 0.92 in the NH. The discrepancy is marked in the respective hemispheric summers (SH r = 0.26 versus NH r = 0.51) and essentially disappears in the respective hemispheric winters (SH r = 0.95 versus NH r = 0.95). The lower overall correlation in the SH may well be influenced by the differential distribution of desert and equatorial rain forest in the two hemispheres. These results do not invalidate Relethford's findings with respect to skin color differences between the hemispheres. They indicate, however, that the differences between the hemispheres in UV radiation are attributable not only to astronomical and climatic effects, but to differences between the hemispheres in the latitudinal distribution of habitable land masses.

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Reply

John H. Relethford[1]* and Richard L. McKenzie[2]

[1]*Department of Anthropology, State University of New York College at Oneonta, Oneonta, New York 13820*

[2]*National Institute of Water and Atmospheric Research, NIWA Lauder, Central Otago, New Zealand*

In my original article (Relethford, 1997), I provided evidence of a hemispheric difference in human skin color. Although the evolutionary reasons for this difference are not known, it was noted that there is evidence for a hemispheric difference in ultraviolet (UV) radiation. Several reasons, including a hemispheric difference in the earth–sun distance, were noted. Chaplin and Jablonski's comment (1998) does not dispute the hemispheric difference in skin color but argues against a hemispheric difference in UV radiation. Because their argument concerns itself with data from the field of atmospheric science, I invited Richard McKenzie, author of many of the cited papers on UV radiation, to participate in this reply.

Model calculations of clear-sky UV radiation indicate that based on recent climatologies of ozone measured from satellites, there are significant hemispheric differences in the latitudinal decreases in UV radiation. Latitude for latitude, the calculated doses are larger in the Southern Hemisphere. In annually averaged doses, the hemispheric differences in erythemally weighted (or "sunburning") UV radiation (McKinlay and Diffey, 1987) are generally less than 10%. However, for doses received during peak months (summer), the differences exceed 15% at latitudes greater than 25°. The hemispheric difference in both mean and maximum UV radiation is shown in Figure 1.

The calculated hemispheric differences arise from the lower column amounts of ozone in the Southern Hemisphere and because the time of closest approach between the earth and sun coincides with the Southern Hemisphere summer. Because of the strong solar zenith angle dependence of UV transmission, most of the annual dose of UV radiation arrives in the summer. These calculations ignore the effects of clouds and aerosols, both of which can have important effects on UV radiation.

Because of instrument intercalibration difficulties, there have been few measurements that directly quantify the magnitude of these geographical differences in UV radiation. The few measurements that have been made with cross-calibrated instruments (e.g., Seckmeyer et al., 1995 and references therein) have shown even larger hemispheric differences (40–60% in erythemal UV radiation), both for clear-sky conditions and for all-weather conditions. The larger differences are attributable in part to differences in tropospheric pollution. However, there are important sampling issues that need to be considered because there can be large geographical differences in cloud cover and pollution. It is unlikely that the measurements that have been made were at sites that were accurately representative of the whole hemisphere.

Recently, satellite data have been used to estimate global patterns of UV radiation doses, including cloud effects. Chaplin and Jablonski's analysis, in which they find smaller hemispheric differences, seems to contradict the results based on clear-sky model calculations and the direct measurements. However, Chaplin and Jablonski pre-

*Correspondence to: Dr. John H. Relethford, Department of Anthropology, SUNY College at Oneonta, Oneonta, NY 13820-4015. Tel: (607) 436-2017. Fax: (607) 436-2653. E-mail: relethjh@oneonta.edu

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